

ORIGINAL RESEARCH

REGIONAL INTERDEPENDENCE OF THE HIP AND LUMBO-PELVIC REGION IN DIVISION II COLLEGIATE LEVEL BASEBALL PITCHERS: A PRELIMINARY STUDY

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ABSTRACT

Background: Pitchers may be at greater risk of injury in comparison to other overhead throwing athletes due to the repetition of the pitching motion. It has been reported that approximately 30% of all baseball injuries occur in the lower body. This may be related to limited hip mobility, which can compromise pitching biomechanics while placing excessive stress on the trunk and upper quarter. Hip motion and strength measurements have been reported in professional baseball pitchers but have not been reported in collegiate pitchers.

Purpose: The purpose of this study was to report preliminary findings for passive hip motion and isometric hip muscle strength in collegiate pitchers and compare them to previously published values for professional level pitchers.

Study Design: Cross sectional study

Methods: Twenty-nine collegiate baseball pitchers (age = 20.0 + 1.4 years, height = 1.88 + 0.06 m; weight = 89.3 + 10.7 kg; body mass index = 25.3 + 2.5 kg/m²) were recruited. Subjects were assessed for hip internal rotation (IR) and external rotation (ER) passive motion, hip anteversion or retroversion, gluteus maximus, gluteus medius, hip internal rotator, hip external rotator strength, and lumbo-pelvic control with the prone active hip rotation test as described by Sahrman. Statistical analysis included calculation of subject demographics (means and SD) and use of a two-tailed t-test ($p > 0.05$).

Results: Fifty-two percent of the right-handed and 50% of the left-handed pitchers demonstrated poor lumbo-pelvic motor control with an inability to stabilize during active hip IR and ER even though isolated strength deficits were not detected at a significant level. There were no significant differences in hip passive motion or gluteus medius strength between right and left-handed pitchers. Differences did exist between collegiate data and previously published values for professional pitchers for IR motion measured in prone and gluteus maximus strength. Hip retroversion was present in 55% of the pitchers primarily in both limbs with four of the pitchers presenting with retroversion singularly in either the stride or trail limb where the ER rotation motion was greater than the IR.

Conclusion: Assessing mobility and muscle strength of the lower quarter in isolation can be misleading and may not be adequate to ensure the potential for optimal pitching performance. These findings suggest that lumbo-pelvic control in relation to the lower extremities should be assessed as one functional unit. This is the first study to explore hip motion, strength, and lumbo-pelvic control during active hip rotation in collegiate baseball pitchers.

Evidence Level: 2

Keywords: Baseball, collegiate, hip, lumbo-pelvic motion

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INTRODUCTION

The repetition of the pitching motion combined with strenuous training schedules place baseball pitchers at a greater risk of injury in comparison to other overhead throwing athletes.¹ Although the majority of injuries occur in the upper extremity, Posner et al found that approximately 30% of all injuries in baseball pitchers occur in the lower body.² Increasing evidence indicates that baseball pitchers are susceptible to femoroacetabular impingement, sports hernias, and groin injuries.³ The development of these conditions are often related to limited hip mobility as proposed by Verrall et al who suggest that hip stiffness is associated with later development of chronic groin injury and may be a risk factor for development of future pathology.⁴ Abnormal hip mobility can also predispose other body regions by compromising normal pitching biomechanics which may induce excessive forces through the glenohumeral joint. This can affect the velocity of the pitch as well as increase the potential risk for injury in the upper quarter.^{5, 3} Specifically, altered hip rotational range of motion has a direct effect on the amount of external rotation torque and horizontal adduction range of motion of the shoulder that occurs during the throwing motion.⁶

In addition to rotational mobility, it is critical for the pitcher to have adequate strength of both the trailing limb (leg on same side as throwing arm) and stride limb (leg opposite side of throwing arm) in order to effectively transfer power through the lower quarter and trunk into the pitching arm.⁷ Adequate strength of the hip abductor muscles demonstrated by good peak hip abductor muscle activity in the trail limb is necessary during the wind-up and early cocking phases in order to stabilize the pelvis and enable optimal stride length for optimal acceleration from the lower quarter.^{7,8}

Over time, the loading patterns specific to individual pitchers that lead to asymmetric patterns can contribute to the development of sport-specific and extremity specific adaptations in hip range of motion.⁹ McCulloch et al found that hip rotation in pitchers at the professional level can be asymmetrical, showing significantly greater internal rotation in the trailing hip compared to the stride limb and significantly greater external rotation in the stride

hip compared to the trailing limb.³ Biomechanical changes that result from mal-alignment of the lower extremities can have an influence on joint loading, mechanical efficiency of muscles, and proprioceptive orientation and feedback from the hip and knee. These adaptations ultimately result in altered neuromuscular function and control of the lower extremities.¹⁰ The resulting faulty movement patterns can further perpetuate irritation to the surrounding tissues of the hip and low back which can occur with increased frequency of accessory and physiologic movements seen with poor lumbo-pelvic control.¹¹

To date, it is unknown whether collegiate level players display the same hip asymmetries as professional level players.³ The presence of a retroversion deformity places the femoral neck in a position of posterior rotation in the frontal plane with the end result of increased external rotation ROM of the hip and associated decrease in hip internal rotation.¹¹ It is often assumed that adequate strength and ROM automatically ensures efficient performance.¹² Although movement patterns are partially dictated by anatomical and biomechanical variables, the neurological control necessary to coordinate smooth movement is often overlooked.^{12,13} During a baseball pitch, it is essential to control the trunk from a position of greatest rotation at arm cocking through the position when the ball is released.¹⁴ The greatest demand for stability of the trunk occurs at stride limb foot contact before ball release.¹⁵ The amount of posterior lumbo-pelvic rotation that exists over the stride limb at foot contact is important since excessive motion can reduce the maximum kinetic values of the pitch.¹⁶ It is therefore necessary to assess trunk stability relative to the rotation in the hip in order to ensure that a pitcher can maintain adequate trunk control as the trunk rotates over the stride limb at ball release.

In a previous study by Sung et al, the increase in axial rotation of the trunk relative to the hip was identified as a significant risk factor for development of low back pain and can occur in conjunction with stiffness in the hip.¹⁷ Van Dillen et al also found that individuals with low back pain often have limited and asymmetrical passive hip rotation.^{18,19} Although this has not been assessed in baseball pitchers, the

assessment of hip rotation in relation to the trunk has been a useful screening tool for other rotational sports such as golf.²⁰

Currently there are no studies exploring range of motion (ROM), strength and motor control of the lumbo-pelvic region during active hip rotation in Division II collegiate level baseball pitchers. Clinical assessment of the hip for passive ROM and strength performed in this study has been used previously in similar populations of young healthy adults.²¹ Hand held dynamometry and digital goniometry have been determined to be efficient and reliable assessments for muscle strength and range of motion.^{21,22} Although there are no previous studies validating the use of this test, stability of the lumbo-pelvic area in relation to the hip has also been previously explored in rotational athletes by Harris-Hayes.²⁷

The purpose of this study was to report preliminary findings for passive hip motion and isometric hip muscle strength in collegiate pitchers and compare them to previously published values for professional level pitchers. Additionally, this study explores the relationship between lumbo-pelvic motor control and active hip rotation by assessing movement of the lumbar spine and pelvis during prone active hip rotation.

METHODS

This study was approved by the university Internal Review Board. Eligible participants read and signed an informed consent prior to enrollment in this study. This cross sectional study involved the assessment of pelvic girdle and hip function of Division II baseball pitchers. Each pitcher was assessed for hip passive ROM, isometric strength, Craig's test, and lumbo-pelvic motor control during active hip rotation during one data collection session. Comparisons were made between right and left handed pitchers and previously established normative values from professional pitchers.

Subjects

Instrumented hip examinations were performed with a digital goniometer and digital dynamometer on a total of 29 collegiate baseball pitchers during the onset of spring training (Table 1). Participants included 15 from the active pitching roster of Azusa

Table 1. *Subject Demographics*

	Age (years)	Height (m)	Weight (kg)	BMI (kg/m ²)
Mean \pm SD	20.0 \pm 1.4	1.9 \pm .06	89.3 \pm 10.7	25.3 \pm 2.5

Pacific University, and 14 participants were from the pitching roster at California State University San Bernardino. Subjects were between the ages of 18 and 30 years with a mean age of 20.0 \pm 1.4 years. The average height of the participants was 1.9 \pm .06 m, average weight was 89.3 \pm 10.7 kg, average body mass index was 25.3 \pm 2.5 kg/m². Both right and left-handed pitchers were accepted into the study including 23 right-handed pitchers and six left-handed pitchers. Subjects had to be asymptomatic in both hips at the time of testing and clear of any known hip pathology. Exclusion criteria included previous hip surgery or any other medical problem that would have limited their ability to participate in full activity during the regularly scheduled 2013-2014 baseball season.

Instruments

For range of motion measurements, a hand held digital goniometer (MicroFet 3, Hoggan Health Industries, West Jordan, UT) was used to measure the subjects hip range of motion. Hand held digital goniometers have shown good reliability when compared to a standard goniometer and inclinometer.²³ For manual muscle testing (MMT), a digital dynamometer (MicroFet 3, Hoggan Health Industries, West Jordan, UT) was used on each subject. The digital hand dynamometer has shown good intra-rater reliability with intraclass correlation coefficient (ICC) ranging from 0.81 to 0.96.²⁴

Pilot Testing

Prior to data collection, a three session pilot training test was conducted using the two examiners involved in the data collection process. One examiner recorded all results and one examiner performed all of the tests and was blinded to the recording of the data outcomes. The tests were performed on 29 subjects. The intra-rater reliability for hip range of motion, strength, and Craig's test was good with a range of ICC_(3,3) = 0.90 to 0.92 and the lumbo-pelvic motor control tests also showed good reliability ICC_(3,1) = 0.93. These values met or exceeded the recommended minimal reliability of 0.90 for clinical measurements.²⁵

Assessment Procedures

Sitting: *Passive Hip IR and ER Passive ROM and Manual Muscle Testing (MMT)*

For all of the assessments, the subjects were examined in their home team training facility and all procedures were explained in detail and demonstrated by the examiners.

Hip IR ROM: For measurement of the hip ROM tests, the subjects were sitting with their legs hanging off the edge of the plinth. The examiner placed one hand at the lateral aspect of the distal thigh and the other on the medial malleoli. The subject was passively moved into hip internal rotation by moving the foot laterally to the end of the available range. The examiner then stabilized the subject's thigh at the point where the hip could no longer be passively moved without inducing movement at the lumbopelvic region and measured with a hand held digital goniometer placed at the lateral malleolus.

Hip ER ROM: *The measurement for external rotation was then performed.* The examiner placed one hand at the medial aspect of the distal thigh and the other on the lateral malleoli. The subject was passively moved into hip external rotation by moving the foot medially to the end of the available range. The examiner then stabilized the subject's leg and measured with a hand held goniometer placed at the medial malleolus (Figure 1).

MMT for Hip Internal Rotators: While seated, the subject's leg was placed in a neutral position of hip rotation and abduction and adduction by the examiner. The examiner placed a stabilizing belt around the hand held digital dynamometer which was placed at the lateral malleolus. The subject was asked to move their foot outward, internally rotating against the resistance of the stabilizing belt attached to the leg of the plinth and digital dynamometer. The force generated by the subject was recorded as the internal rotator muscle force in kilograms (Figure 2). Two trials were recorded and averaged for each extremity.

MMT for Hip External Rotators: While seated, the subject's leg was placed in a neutral position of hip rotation and abduction and adduction by the examiner.



Figure 1. *Hip ROM measured with digital goniometer*

The examiner placed a stabilizing belt around the hand held digital dynamometer placed at the medial malleolus. The subject was asked to move their foot inward, externally rotating against the resistance of the stabilizing belt attached to the leg of the plinth and digital dynamometer. The force generated by the subject was recorded as the external rotator muscle force. Two trials were recorded for each extremity.

Prone: Passive HIP IR, ER, lumbopelvic control and Gluteus maximus MMT

Passive Hip IR and ER: Passive hip ROM testing was also conducted using the methods defined by Sahrman.^{26,27} To assess hip passive rotation, the subject was placed in the prone position on the plinth, with the femur placed in neutral position by the examiner. The subject flexed the knee to 90 degrees. The subject's thigh was abducted 15 degrees to place the Tensor Fascia Lata (TFL) on slack. The examiner placed one hand on the pelvis of the test leg. The examiner's opposite hand was used to move the subject's leg into an internally rotated position by moving the subject's foot laterally. Once the examiner felt the anatomic block or movement of the



Figure 2. *MMT Measured with digital dynamometer*

pelvis, maximal passive internal rotation mobility of the hip was measured using a digital goniometer placed parallel to the tibia. The measurement was recorded and averaged between two trials. The same position was used for the measurement of external rotation. The examiner kept one hand on the pelvis and the other hand was used to move the foot medially while maintaining the 90 degree flexed position of the knee. The examiner continued to move the foot until the examiner felt the pelvis move. Once the examiner felt the anatomic block or movement of the pelvis, maximal passive external rotation mobility of the hip was measured with a digital goniometer placed parallel to the tibia. The measurement was recorded, with two trials performed, and the average of the two trials was used for data analysis.

Craig's Test

Further testing for femoral anteversion and retroversion was conducted using the Craig's test. The subject was in the prone position with the knee flexed to 90 degrees. The examiner palpated the same side greater trochanter. The femur was passively rotated through hip internal rotation and external rotation until the position at which the trochanter was parallel to the plinth placing it in the most prominent

lateral position, confirmed with manual palpation. The amount of femoral internal rotation was measured by placing a digital goniometer along the tibia. Two trials were performed and recorded. An angle less than 8 degrees was determined to be a position of retroversion and an angle greater than 15 degrees was determined to be a position of anteversion.²⁸ Intra-tester reliability is high for the Craig's test and is reported in the literature to range from 0.80–0.90.²⁹⁻³¹

Prone lumbopelvic control test: Testing was conducted using the methods defined by Sahrman.^{26,27,32} To assess prone active rotation, the subject was placed in a prone position on the plinth with the femur placed in neutral position in regards to IR/ER or abduction or adduction by the examiner. The subject flexed the knee to 90 degrees. The examiner palpated the pelvis at the level of the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS) bilaterally to assess whether the pelvis and lumbar spine maintained a neutral position throughout the test. The subject was asked to maintain the 90-degree position of the knee and to actively perform femoral IR through their full available ROM (which was visually compared to the passive measurements taken earlier) while maintaining the knee at 90 degrees of knee flexion. As the subject actively rotated the femur the examiner assessed the pelvis for any superior or inferior movement or the ASIS or PSIS. The subject then performed active femoral ER through their full available ROM while the examiner assessed for movement in the pelvis exactly as was performed for IR. This was performed on both lower extremities. A negative test was defined as the subject independently performing active femoral IR and ER throughout their full available ROM without simultaneous movement in the pelvis or trunk (Figure. 3). Criteria for a positive test included early or excessive pelvic or low back rotation with active rotation of either hip (Figure 4).¹¹

Reliability of the MSI exam has been substantiated by Harris-Hayes and Van Dillen where inter-tester reliability of classification of patients with LBP when therapists used the MSI classification system was substantial.³³ The Movement System Impairment (MSI) exam, which encompasses the prone rotation test, has demonstrated good reliability with a kappa



Figure 3. Negative MSI Exam for independent active femoral IR without simultaneous movement in the pelvis or trunk.



Figure 4. Positive MSI Exam demonstrating excessive pelvic or low back rotation with active rotation.

coefficient of 0.81 for classification using entire MSI exam.^{34,35} The prone hip rotation test has been used by Scholtes et al to identify early lumbo-pelvic motion in athletes with low back pain who played rotation related sports.³⁶ The presence of greater lumbo-pelvic rotation is frequently associated with low back pain, indicating that clinical assessment of early lumbo-pelvic movement in relation to the hip can be of great importance in individuals who play rotational sports.³⁷

Gluteus Maximus MMT: The subject was positioned prone with bilateral ASIS on the end of the plinth, leaning over the edge of the plinth, while feet maintained contact with the ground. The knee of the test leg was flexed to 90 degrees. The examiner lifted the test leg with one hand and stabilized the pelvis with the other hand to assess the amount of available ROM the subject had in hip extension. The subject's leg was returned to neutral (hip flexion 90 degrees with 90 degrees knee flexion). The stabilizing belt

attached to the leg of the plinth was placed around the hand held digital dynamometer on the distal posterior surface of the subject's femur above the knee. The examiner instructed the subject to hold the position of the leg lifted off the table with the knee flexed as maximal resistance was applied by the stabilizing belt attached to the leg of the plinth. The maximal force measured by the hand held digital dynamometer was recorded. Two trials were recorded for each extremity.

Sidelying Gluteus Medius Manual Muscle Test

Gluteus Medius MMT: The subject was placed in the sidelying position with the test leg on top. The examiner placed one hand on the pelvis and placed the other hand under the test leg. The examiner lifted the test leg into hip abduction to assess the amount of available ROM that the subject had in hip abduction. The examiner's other hand stabilized the pelvis to avoid the subject from rolling forward or backward during the test. The subject's leg was returned to a neutral position. The subject was then asked to raise their leg off of the table to mid range

of hip abduction without rotating the pelvis forward or backward. In this position, the examiner placed the stabilizing belt around the hand held digital dynamometer on the lateral mid femur above the knee. The examiner instructed the subject to hold the position against the resistance of the stabilizing belt secured on the underside of the plinth. The maximal force measured by the hand held digital dynamometer was recorded. Two trials were recorded for each extremity.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS version 22.0 for Windows® (IBM SPSS, Chicago, IL). Participant descriptive data was calculated and reported as the mean and standard deviation (SD). During the pilot test, rater reliability was determined by the ICC model (3, k). The T-Test was used with a Bonferoni correction to measure mean differences between variables. Statistical significance was considered to be $p < 0.05$.²⁵

RESULTS

Right Handers

For right-handed pitchers, the mean sitting IR ROM for the trail limb (right) was $33.6^\circ \pm 9.4^\circ$ versus the forward limb of $35.6^\circ \pm 8.1^\circ$. There was no significant difference in seated IR ROM between the trailing and forward limb ($p = 0.22$). For prone IR ROM, the trail limb (right) was $24.8^\circ \pm 8.6^\circ$ versus of forward limb (left) of $27.0^\circ \pm 8.9^\circ$. There was no significant difference in prone IR ROM between the trailing and forward limb ($p = 0.19$).

For sitting ER ROM, the mean trail limb was $36.9^\circ \pm 9.8^\circ$ versus the forward limb $39.4^\circ \pm 10.3^\circ$. There was no significant difference in sitting ER ROM between the trailing and forward limb with the seated measurement ($p = 0.08$). For prone ER ROM, the mean trail limb was $43.2^\circ \pm 8.0^\circ$ versus the forward limb $46.3^\circ \pm 12.1^\circ$. There was no significant difference in sitting ER ROM between the trailing and forward limb with the prone measurements ($p = 0.11$).

Left Handers

For left handed pitchers, the mean sitting IR ROM for the trail limb (left) was $33.0^\circ \pm 9.5^\circ$ versus of forward limb (right) of $32.1^\circ \pm 7.4^\circ$. There was no significant difference in seated IR ROM between the

trailing and forward limb ($p = 0.80$). For prone IR ROM, the trail limb (left) was $20.5^\circ \pm 8.4^\circ$ versus of forward limb (right) of $17.3^\circ \pm 7.9^\circ$. There was no significant difference in prone IR ROM between the trailing and forward limb ($p = 0.29$).

For sitting ER ROM, the mean trail limb was $43.2^\circ \pm 13.6^\circ$ versus the forward limb $45.2^\circ \pm 13.6^\circ$. There was no significant difference in seated ER ROM between the trailing and forward limb ($p = 0.56$). For prone ER ROM, the mean trail limb was $49.4^\circ \pm 7.3^\circ$ versus the forward limb $48.9^\circ \pm 13.6^\circ$. There was no significant difference in prone ER ROM between the trailing and forward limb ($p = 0.84$).

Comparison of Left and Right Handed Pitchers

When comparing the trailing limb of right and left pitchers there were no significant differences in seated IR and prone IR ROM measurements ($p = 0.85$ and $p = 0.79$ respectively) (Table 2). For ER ROM, there were no significant differences in seated ER and prone ER measurement ($p = 0.38$ and $p = 0.87$ respectively) (Table 3). When comparing the forward limb of right and left pitchers there was no significant difference in seated IR and prone IR ROM measurements ($P = 0.51$ and $p = 0.72$ respectively) (Table 2). For ER ROM of the forward limb, there was no significant difference in seated ER and prone ER measurement ($P = 0.31$ and $p = 0.77$ respectively) (Table 3).

Comparison of Collegiate Pitchers' data to Previously Established Values for Professional Pitchers

The trailing limb of the right-handed pitchers sitting IR ROM was $33.6^\circ \pm 9.4^\circ$ as compared to values for professional baseball pitchers of $37.7^\circ \pm 5.70^\circ$, demonstrating an approximate four degree difference.³⁹ The trailing limb prone IR ROM was $34.45^\circ \pm 8.51^\circ$ compared to professional values of $34.6^\circ \pm 4.0^\circ$, demonstrating an approximate 0.2 degree difference.³⁸

The stride limb of the right-handed pitchers sitting IR ROM was $35.6^\circ \pm 8.1^\circ$ compared to values for professional baseball pitchers of $37.0^\circ \pm 5.60^\circ$, demonstrating an approximate one degree difference. The stride limb prone IR ROM was $27.0^\circ \pm 8.9^\circ$ compared to professional values of $34.4^\circ \pm 6.0^\circ$, demonstrating an approximate seven degree difference.³⁸

Table 2. Comparison of hip internal rotation ROM of the trail limb and forward limb in Right and Left Handed Pitchers						
	IR Trailing Limb (Sitting)	IR Forward Limb (Sitting)	p=Value	IR Trailing Limb (Prone)	IR Forward Limb (Prone)	p=Value
Right- Handed Pitchers Mean ± SD	33.6° ±9.4°	35.6° ±8.1°	p=0.22	24.8° ±8.6°	27 ±8.9°	p=0.19
Left-Handed Pitchers Mean ± SD	33° ±9.5°	32.1° ±7.4°	p=0.80	20.5° ±8.4°	17.3 ±7.9°	p=0.29
Right- versus Left-Handed Pitchers P=Value	p=0.85	p=0.51		p=0.79	p=0.72	
<i>IR= internal rotation</i>						

Table 3. Comparison of hip external rotation ROM of the trail limb and forward limb in right and left handed pitchers						
	ER Trailing Limb (Sitting)	ER Forward Limb (Sitting)	p-Value	ER Trailing Limb (Prone)	ER Forward Limb (Prone)	p-Value
Right- Handed Pitchers Mean ± SD	36.9° ±9.8°	39.4° ±10.3°	p=0.08	43.2° ±8.0°	46.3 ±12.1°	p=0.11
Left-Handed Pitchers Mean ± SD	43.2° ±13.6°	45.2° ±13.6°	p=0.56	49.4° ±7.3°	48.9 ±13.6°	p=0.84
Right- versus Left- Handed Pitchers p=Value	p=0.38	p=0.31		p=0.87	p=0.77	
<i>ER= external rotation</i>						

Force measures were combined for right and left-handed pitchers. MMT outcomes for the internal rotators were 55.33 kg ± 13.62 for the stride limb and 49.17 kg ± 13.24 for the trailing limb (Table 4). MMT outcomes for the external rotators were 38.10 kg ± 8.45 for the stride limb and 36.45 kg ± 8.80 for the trailing limb. MMT outcomes for the gluteus maximus were 90.55 kg ± 20.32 for the stride limb and 90.93 kg ± 24.60 for the trailing limb. MMT outcomes for the gluteus medius were 40.58 kg ± 10.85 for the stride

limb and 42.90 kg ± 10.23 for the trailing limb. These were the only values that were able to be compared to previously established values for professional baseball players of 41.9 kg ± 7.2 for the stride limb and 41.4 kg ± 6.3 for the trailing limb (Table 4). This represents a difference of 1.32 kg and 1.50 kg respectively.

Craig's Test

Sixteen out of 29 (55%) pitchers demonstrated retroversion in both limbs with four of the pitchers pre-

Table 4. Comparison of strength values between collegiate and professional pitchers.								
	IR Stride Limb	IR Trail Limb	ER Stride Limb	ER Trail Limb	Gluteus Maximus Stride Limb	Gluteus Maximus Trail Limb	Gluteus Medius Stride Limb	Gluteus Medius Trail Limb
Combined Right and Left Hand Pitchers Mean \pm SD	55.33 kg \pm 13.62	49.17 kg \pm 13.24	38.10 kg \pm 8.45	36.45 kg \pm 8.80	90.55 kg \pm 20.32	90.93 kg \pm 24.60	40.58 kg \pm 10.85	42.90 kg \pm 10.23
Professional Values³⁸ Mean \pm SD							41.9 kg \pm 7.20	41.40 kg \pm 6.3
IR= internal rotators; ER= external rotators								

senting with retroversion singularly in either the stride or trail limb, which was consistent with their ROM findings of greater hip ER than IR ROM.

Lumbo-pelvic control

Fifty-two percent of right-handed pitchers were positive on their trailing limb for the presence of early or excessive lumbopelvic rotation either during prone active IR or ER and 43% were positive on the stride limb. Fifty percent of left-handed pitchers were positive on the stride limb, while all left-handed pitchers were negative on the trail limb. Considering both right and left-handers together resulted in 37% being positive on trail limb and 45% positive on stride limb for the inability to stabilize the lumbo-pelvic region during active IR or ER rotation of the hip.

DISCUSSION

Currently there are no studies exploring ROM, strength, and motor control of the lumbo-pelvic region during the prone active hip rotation test in collegiate level Division II baseball pitchers. These preliminary findings in collegiate level Division II baseball pitchers were inconsistent with the findings of McCulloch et al comparing rotation measurements between the stride and trailing limb.³ This may be due to the professional level status of the pitchers in McCulloch's study who would have had increased overall pitching time as compared to the collegiate level pitchers in the current study. Although the results of the current study showed

differences between the two limbs IR and ER PROM, they did not reach a statistically significant level.

The results of the current study revealed a 7 degree difference in stride limb IR when compared to the previously established normative values for IR in professional players measured in the prone position. The presence of this deficit may prove to be problematic as time progresses for pitchers and other athletes where the demand for hip rotation is high. Limitations of hip ROM may result in changes at the lumbo-pelvic region as a compensation strategy; especially during activities that require hip rotation such as golf, racquetball, and baseball.²⁷

Fifty-five percent of the pitchers in the current study presented with hip retroversion where an angle less than eight degrees of femoral internal rotation in the prone position with the greater trochanter positioned parallel to the plinth was determined to be a position of retroversion. This can be highly problematic as the retroverted orientation of the hip may give rise to problems of impingement between the femoral neck and anterior acetabulum.³⁹ Prolonged and severe impingement resulting from sporting activities can lead to progressive degenerative changes at the hip where loads greater than eight times body weight have been reported during competitive sports.⁴⁰

The unique part of this investigation that has not been previously explored is the ability of pitchers to maintain lumbo-pelvic motor control during the prone

active hip rotation test as described by Sahrman.¹¹ The close proximity of the hip to the lumbo-pelvic region may predispose the low back to excessive rotational forces when more proximal regions need to compensate for limited rotation at the hips. The regional interdependence of the low back and hips was assessed using the MSI prone active IR and ER test. Results of the current study indicate that 52% of the right-handed pitchers were positive for excessive lumbo-pelvic rotation with active hip rotation in their trailing limb and 42% in the stride limb indicating that the pitchers had early or excessive lumbo-pelvic movement with active hip rotation. This was characterized by dysfunctional coupled movement of the pelvis and the hip where the pelvis rotated prior to the hip reaching the limits of available active ROM in the prone position. Fifty percent of left-handed pitchers were positive in the stride limb while none of the left-handed pitchers had excessive lumbo-pelvic movement with active hip rotation in the trailing limb. Previous research has linked early lumbo-pelvic motion with an increased incidence of low back pain.⁴¹

Although the strength findings of the gluteus maximus in the collegiate population were similar to the professional players, adequate strength and ROM alone may not be sufficient to ensure optimal pitching performance.¹² The regional interdependence of the lumbo-pelvic region and hip should be assessed to determine if excessive motion occurs in the lumbo-pelvic region with active hip rotation. Improving lumbo-pelvic movement patterns by reducing lumbo-pelvic motion during hip rotation could be an important component of improving efficiency of the baseball pitch as well as preventing injury to the low back and shoulder.⁴¹

The limitations of the current study include a small sample size of 29 pitchers from two Division II baseball teams in Southern California. The years of pitching experience, pitch count, or training methods of each team were not considered in this study. Future research should include a comparison of the incidence of low back pain with larger samples sizes. There were no cited values for active control of hip rotation in professional athletes. Data on neuromuscular control of hip IR and ER in the prone position should be collected for pitchers at the other levels of

baseball including professional, collegiate, and high school.

CONCLUSION

Strength findings of the gluteus maximus in the collegiate population were similar to the previously reported values of professional players. Simple range of motion comparisons performed between outcomes recorded herein for collegiate players revealed a 7-degree difference in stride limb IR when compared to the previously established values for IR in the prone position recorded for professional pitchers. Although strength and ROM are often assessed in the lower quarter, they may not be sufficient to optimize potential pitching performance.¹² The results of the current study indicate that lumbo-pelvic motor control deficits were present during testing of both the stride and trailing limb in greater than 50% of the pitchers tested. The early lumbo-pelvic motion with prone active hip rotation may represent an abnormal pattern of movement that may predispose the low back to excessive rotational forces as the low back compensates for limited rotation at the hips during rotational sports. Further research should focus on the assessment of prone lumbo-pelvic control with active hip rotation in baseball pitchers and all athletes that participate in high demand rotational sports.

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